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HIGH SPEED ANTIMISSILE COMMAND INERTIAL
PRECISION GUIDANCE SYSTEMS

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TRANSLATOR NOTE This article is a written translation of a voice recording of a lecture made by the author at the Moscow International Ballistic Missile Defense Symposium on 24 November 1993. It primarily discusses guidance and control methods associated with close and medium range high speed antimissile missiles to intercept in the atmosphere ballistic type missile warheads. Exposition is primarily of command inertial guidance methods opted for to use in high speed missiles within dense atmosphere as well as control methods associated with predetermined impact points. It gives the structures currently associated with this type of guidance method control system. The author of the lecture is a member of the Russian "Trail Blazer" (Новатор) Design Bureau, specializing in the development of high speed antimissile missiles. As far as the lack of illustrations in the original article is concerned, the appended Fig.'s in the article were added as supplements by the translator on the basis of the contents of the recorded lecture and the principles it concentrated on. They are only provided for reference.

This report is involved with the guidance of medium and close range high speed antimissile missile interception devices. The range of combat altitudes is 5-45km. As far as ranges are concerned, the first case is less than 80km. The second case is 20km. The guidance accuracies required by each type of antimissile missile are on the order of 3-4 m in accordance with final target miss quantities. When designing high precision guidance systems over relatively small distances, option is normally made for the use of automatic homing guidance principles. However, opting for the use of homing guidance with regard to high speed antimissile missiles in the atmosphere becomes a very difficult problem to solve. This is related to problems of aerodynamic heating associated with warhead cowlings. In that case, is there a possibility or not to opt for the use of remote control guidance systems in order to guarantee required precision?

If one wishes to successfully resolve these problems, it is necessary to base oneself on the precision which current radars are capable of reaching in order to guarantee it. Setting out from the precision required by interception devices associated with the given distance ranges, the root mean square values associated with measured differences in relative angular coordinates of target warheads and antimissile missiles should be on the order of 50-100 microradians (μR). At the present time, this type of radar precision is attainable. In conjunction with this, opting for the use of two types of guidance method, it is possible to guarantee the required guidance precision--pure command guidance and command inertial guidance.

When opting for the use of pure command guidance--sending control commands from the ground toward antimissile missiles--they do not require accurate conversions to be control commands associated with execution structures. For example, if required acceleration commands are sent to missiles, then, control systems on missiles need only take these accelerations and produce them. At this time, all guidance operations use ground computers for their realization.

This type of guidance method possesses the advantage of greatest simplicity. However, it possesses severe shortcomings. As far as this type of missile having very short response times is concerned--when guided within the atmosphere--the usable overload time function change curves vary very greatly. As a result, there is a need for very high control command sending frequencies. Because of this, in complicated interference environments, it is sometimes possible to generate situations associated with nonpredetermined equipment operating interruptions. As far as missile control is concerned, this may then possibly lead to interruptions. Besides this, in order to obtain the necessary precision associated with interception device control parameter estimate values at the times in question, radar station high frequency queries to interception devices are needed.

When opting for the use of command inertial guidance, the portion of control systems on missiles is very, very greatly expanded. In this is included inertial control systems on missiles and computers on missiles. This is then capable, to a very great extent, of raising the autonomy of on board missile control systems, thereby increasing their counter jamming capabilities. Besides this, this type of equipment existing on missiles uses radar station measurement information in order to compensate for antimissile missile motion parameters determined by inertial navigation control systems on missiles to supply conditions, thus increasing guidance precision. /37

As far as selection of guidance methods is concerned, any distribution of guidance between equipment on missiles and on the ground is characteristically related to target motion parameters. Among these are included whether or not targets are maneuvering and whether this type of target maneuver can be identified or not. Selection of the guidance methods discussed above--in contrast to accuracies associated with measurement equipment on missiles and the ground--are related to such factors as antimissile missile kinetics characteristics as well as jamming environments, and so on.

With regard to control methods, it is possible to have two types of primary methods in this--ratio control methods and predetermined impact point control methods. The first type of

method is primarily used in the situations which follow--when target tracks are not capable of being predicted very well, that is, option for use is made when controlling against maneuvering targets. This type of control method possesses the following characteristic--in reality, all guidance operations are completed on antimissile missiles. From the ground, coordinate difference values associated with targets and interception devices on missiles are given. In accordance with differences in accuracies associated with navigation system speed measurements by navigation systems on antimissile missiles, relative velocity vectors on missiles are sent out or simply target speed values.

Predetermined impact point control methods are reasonably utilized in control associated with nonmaneuvering targets. They are built on a foundation of being able to accurately predict interception device and target tracks as well as their meeting points. In conjunction with this, there is a requirement to guarantee minimum energy control of interception devices, that is the ability to supply maximum protected air space. When opting for the use of this type of control method, guidance operations are not completely realized on missiles. Guidance operations on board missiles can be reduced. Operational tasks associated with target intercept or encounter can be moved to ground computer systems in order to be completed.

To cite an example, as far as our plan to study one type of command inertial control system associated with the intercept of nonmaneuvering targets is concerned, in the system, option is made for the use of predetermined impact point control methods. With regard to the essence of this type of control method, it is as shown in Fig.1.

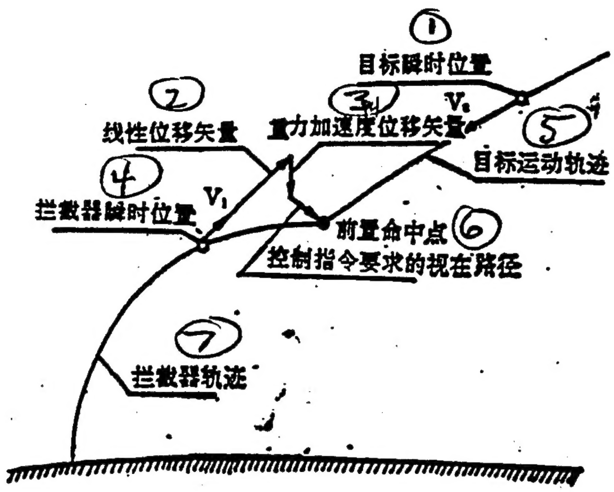

Fig.1 Predetermined Impact Point Control Methods Associated with the Intercept of Nonmaneuvering Ballistic Missile Targets

Key: (1) Instantaneous Target Position (2) Linear Displacement Vector (3) Gravity Acceleration Displacement Vector (4) Instantaneous Interception Device Position (5) Target Motion Track (6) Apparent Course Required by Predetermined Impact Point Control Commands (7) Interception Device Track

Fig.1 shows a simplified intercept schematic in a vertical plane. Interception device and target motion tracks respectively make use of rising and descending curves for their display. A certain instantaneous position of interception devices and targets on tracks are shown by the use of round circles with hollow centers. Moreover, impact points are displayed by the use of solid circles. Interception device displacement to impact points can be represented using a composition of three vectors.

The first vector is linear displacement or is designated as the linear predicted quantity. In reality, it is the product of intercept device velocity vectors at the times in question and the remaining time to impact point.

The second interception device displacement vector is created due to the force of gravity acting on interception devices. In the Fig., a vertical downward free falling body vector is used in order to express it. It is a dual integral quantity associated with gravitational acceleration.

The third interception device replacement vector is created by all main thrust effects. This includes the effects of applied incoming flow aerodynamic forces as well as applied engine control forces. This vector is precisely the control command during aircraft missions. In reality, it is one type of required apparent course. It is also nothing else than the path that antimissile missiles need to travel under the effects of control commands in inertial space.

Ground guidance system structures corresponding to this control method are as shown in Fig.2. /38

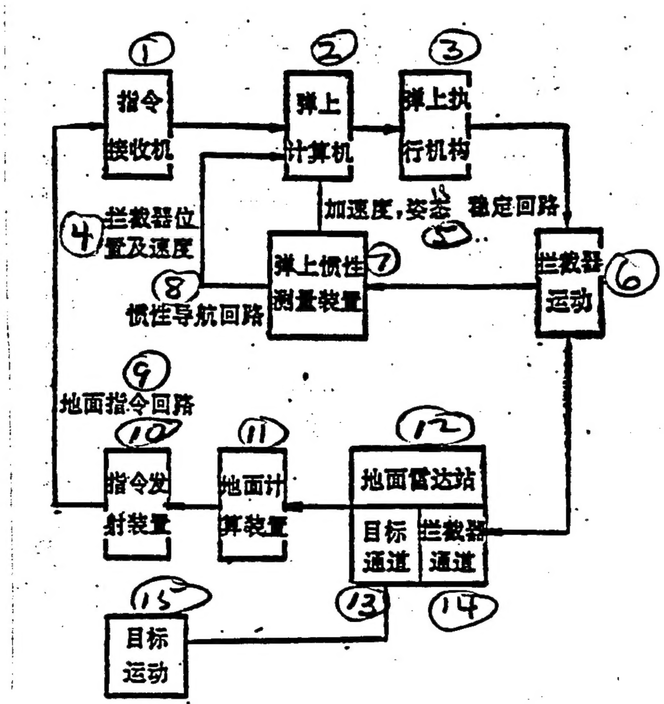

Fig.2 Command Inertial Guidance Control System Structure

Key: (1) Command Receiver (2) On Board Missile Computer (3) On Board Missile Execution Structures (4) Interception Device Position and Speed (5) Acceleration, Attitude, and Stability Circuit (6) Interception Device Movement (7) On Board Missile Inertial Measurement Systems (8) Inertial Navigation Circuit (9) Ground Command Circuit (10) Command Transmission System (11) Ground Computer Systems (12) Ground Radar System (13) Target Channel (14) Interception Device Channel (15) Target Movement

Here, the several components below are shown simplified:

ground radar stations possessing two target and interception device channels;
ground computer systems;
antimissile missiles;
on board missile inertial systems, and on board missile computers.

From guidance systems, it is possible to separate out three circuits.

The first circuit is the outside circuit. It makes use of radar signals and antimissile missile motion parameters given on board missiles in order to close. As far as antimissile missile movement parameters are concerned, here, they refer to velocity vectors associated with antimissile missile locations. They are formed by inertial navigation operations. In accordance with this information as well as target information, ground computer systems calculate out estimated quantities for interception devices and target movement parameters, calculating contact equations and needed apparent paths. After that, they are transmitted onto missiles.

The second circuit is included within the first circuit. It is realized dependent on equipment on board antimissile missiles. It makes use of inertial navigation system information in order to close. In accordance with this information, computers on board missiles calculate out apparent paths which antimissile missiles have already traversed in past periods. From this, it is possible to precisely determine the remaining apparent path. On this foundation, required control signals are formed.

The final circuit is included within a single circuit. It is the stability circuit. The function is to carry out accelerations which must be applied.

When designing flow plans for this type of information, it is required to guarantee the characteristics of given guidance systems and missiles for not having malfunctions and very high strengths, dynamic performance of control systems on board missiles, and so on. In this way, it is possible to take systems directly to limit levels. This is also nothing else than taking guidance precision levels and raising them to error levels which cannot be further eliminated and are actually equal to relative coordinates associated with radar station measurements of interception devices and targets.

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